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A DYNA-METRIC ANALYSIS OF THE ROK AIR FORCE MAINTENANCE RATIO REQUIREMENT

THESIS

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Table of Contents

Page

Acknowledgements....................................ii

List of Tables......................................v

Abstract..vi

I. Introduction.....................................1

Background..1
Statement of the Problem............................2
Definitions...3
Research Objectives.................................5
Research Questions..................................6
Availability of Data................................6

II. Background......................................7

Situation...7
Overview of Dyna-METRIC Model.......................8
Assumptions for Dyna-METRIC.........................12
Problem and Dyna-METRIC Model.......................13

III. Methodology....................................15

Overview..15
Evaluation Model....................................16
Impacts of Dyna-METRIC Assumptions
on the Experimental Design..........................18
Research Data Collection and Scenario...............20
Research Data Preparation...........................22
Experimental Design.................................27
Methodology and Design Limitations..................29

IV. Results...31

Overview..31
Presentation of Research Results....................32
Analysis of Results.................................42

V. Conclusions......................................44

Summary of Research Effort..........................44
Conclusions...45
Recommendations.....................................46

Page

Appendix A: Acronym Definition....................49

Appendix B: Sample Input Format (Version 4.3)............51

Bibliography..53

Vita..55

List of Tables

Table Page

1. Radios and Their Components........................23
2. Application Fraction Factor (UHF)..................25
3. Application Fraction Factor (VHF)..................26
4. Radio Backorders (Cann) (UHF)......................33
5. Radio Backorders (Cann) (VHF)......................33
6. Available Radios on Day 30 (Cann) (UHF)............34
7. Available Radios on Day 30 (Cann) (VHF)............34
8. Radio Backorders (No Cann) (UHF)...................35
9. Radio Backorders (No Cann) (VHF)...................35
10. Detailed Pipeline Segment (Cann) (UHF)............36
11. Detailed Pipeline Segment (Cann) (VHF)............36
12. Detailed Pipeline Segment (No Cann) (UHF).........37
13. Detailed Pipeline Segment (No Cann) (VHF).........37
14. Consumed/Required Components (UHF)................38
15. Consumed/Required Components (VHF)................39
16. New Factors (UHF).................................40
17. New Factors (VHF).................................41

AFIT/GLM/LSM/84S-34

Abstract

This (thesis) ~~research~~ develops a methodology to investigate the impact that current logistics support policies have on the Republic of Korea Air Force's maintenance intrabase radio net using Rand's Dyna-METRIC inventory model. Current stockage policies for radios and their components were analyzed using a hypothetical war scenario. The results of this study reveal that the authorized stock levels for radio components may be inadequate thereby reducing serviceable radios in a conflict. The methodology developed for this research is applicable to many non-aircraft components.

Originator supplied keywords include: (cont on p 57)

A DYNA-METRIC ANALYSIS OF THE ROK AIR FORCE MAINTENANCE RADIO REQUIREMENT

I. Introduction

Background

An adequate and reliable maintenance communication network is essential for a viable aircraft maintenance capability. Improvements in maintenance communication may have significant impact on combat capability. As Alan A. Blomgren states:

> If one could quantify the hours wasted by Air Force maintenance people waiting because they can't communicate, one could easily justify the expense of whatsoever new gadgets technology will bring [20:introduction].

Thus, improvements in the maintenance communication system merit intensive research.

As part of the maintenance communication system, the Maintenance Intrabase Radio Net is used to direct and control a combat unit's aircraft maintenance effort. Generally, a Maintenance Control Center with a UHF or VHF base station communicates by voice with a number of mobile radio stations usually located on or near the flight line to coordinate repair, servicing, and rearming of aircraft (20:page B-1). Such activity must be accomplished with dispatch in order to sustain rapid turn-around of aircraft engaged in combat.

The Republic of Korea Air Force (ROKAF) has procured mobile radio equipment from such vendors as General Electric and Motorola and maintains it at the Electronics Repair Depot (ERD) at Taegu Air Base. The ERD, the only radio repair facility of its kind, is located at least one hundred miles to the south of most of the combat units that it supports.

Transportation between these combat units and the ERD requires anywhere from several days to several weeks (9). Under adverse combat conditions, this transportation time is expected to increase drastically. Furthermore, in combat, the reliability of maintenance radios is expected to decline, relative to peacetime reliability, because of increased utilization and rough handling.

At present no spare radios are authorized for the combat units or for the ERD (9). Broken radios are shipped to the ERD, repaired with available spare components, and returned to the originating combat unit. The present wartime stockage level requirements for radio spare components at the ERD are determined by multiplying the peacetime rate by a factor of three (9).

Statement of the Problem

During combat operations, maintenance communications may be degraded if an insufficient number of maintenance radios are available. The wartime breakage rates for these radios may be such that the wartime stockage levels for spare components could be depleted sooner than expected. Moreover, the expected increase in repair and transportation time may tie up a significant number of radios in the repair pipeline, and hence spare radios may be required to offset potential shortfalls.

Definitions

Back Order. A demand for an item requisitioned by ordering activities which is not immediately available for issue, but which is recorded as a stock commitment for future issue. It includes demands for stocked items processed for purchase for direct shipment but not yet shipped (15:83).

Cannibalization. The authorized removal of a specific assembly, sub-assembly, or component from one equipment end-item for installation on another equipment end-item to meet priority requirements with an obligation to replace the removed item(s) (15:107).

Line Replaceable Unit (LRU). An item that is normally removed and replaced as a single unit to correct a deficiency or malfunction on a weapon or support system at the operating location. This may include avionics, hydraulics, pneumatics, and other recoverable parts. LRUs may be disassembled into separate components (Shop Replaceable Units (SRUs)) (15:393).

Maintenance Control Center. A facility from which maintenance command and control can be directed.

Maintenance control is the staff function responsible for scheduling and directing the maintenance efforts by centralized control of all de-centralized maintenance functions. To execute these responsibilities, there are functional elements: job control, material control, plans and scheduling, and documentation. Of these, job control is responsible for the overall command and control of the maintenance effort (7:294).

Maintenance Intrabase Radio Nets. Radio nets provide the mode for communication between the maintenance control center and each maintenance function. A maintenance control center with UHF or VHF base station communicates by voice with a number of mobile radio stations to coordinate repair, servicing, and rearming of aircraft (20:page B-1).

Mean Time Between Demand (MTBD). The average number of operating hours accumulated on a unit before it is removed from the next higher assembly and replaced due to failure or preventive maintenance with a serviceable unit (15:440).

Not Mission Capable (NMC). A status code meaning that the system or equipment cannot perform any of its primary missions. It can be followed by a reason code meaning maintenance (M), supply (S), or both (B) (15:461).

Not Reparable This Station (NRTS). The status of an item of unserviceable, reparable equipment determined to be not reparable at the level activity responsible for repair due to lack of authorization, technical skills, parts, facilities, funds, time, or any other cause (15:479).

Reliability. The probability that a system, subsystem or equipment will perform a required function under specified conditions without failure for a specified period of time (15:576).

Shop Replaceable Unit (SRU). A component of an LRU which can be removed from the LRU at an intermediate repair facility. SRUs may be locally authorized and maintained to support intermediate level repair of the LRU (15:627).

Wartime Stockage Level. The quantity of an item maintained on hand at a stockage point to meet anticipated increased demand in wartime (11).

Research Objectives

The objective of this study is to provide a methodology for determining wartime requirements for maintenance radios and their spare components. To assure adequate wartime availability of maintenance radio nets, we need information to help us identify those resources and processes that most constrain wartime capability. We have had to rely heavily on our own logic, experience, and intuition when we plan, assess, and manage logistics support for future wars. In peacetime, we can iteratively modify and improve peacetime support by responding to periodic (e.g., weekly, monthly) summaries and analyses of current status, support productivity, and exercises. Unfortunately, we cannot observe directly how those and other related peacetime decisions affect our wartime capability because both the planned wartime operational demands and the support system resources and processes differ so drastically from those experienced in peacetime.

Research Questions

1. Are there sufficient quantities of spare radio components authorized for wartime at the Electronics Repair Depot at Taegu Air Base?

2. If the authorized spare part stocks are not correct, what changes in authorized levels are in order?

3. Should spare radios be authorized for the combat units in order to compensate for possible increase in the number of radios in the repair pipeline? If so, how many spare radios are required for each combat unit?

Availability of Data

The data collection plan was designed to avoid any possible exposure of the combat capability of the ROKAF in peacetime and wartime. This exposure problem is sensitive in that if deficiencies exist, this issue could be exploited by our adversaries. Therefore, rather than approach the problem directly, we sought to demonstrate a methodology for investigating the problem using hypothetical scenario data where required.

II. Background

Situation

Every combat unit is authorized and provided with a maintenance radio intrabase net to achieve the goal of fast turn-around for the combat aircraft which are assigned to it. The quantity of radio equipment is in proportion to the size of maintenance forces. The size of maintenance forces differs according to weapon system and the number of aircraft which are assigned (9).

When radios are out of commission, they have to be shipped to the ERD, repaired with appropriate spare components, and returned to the originating unit. Transportation between these combat units and the ERD requires anywhere from several days to several weeks because the ERD, the only ROKAF radio repair facility of its kind, is located at Taegu Air Base, at least one hundred miles to the south of most of the these combat units. Radio repair facilities are not available in the vicinity of combat units. Furthermore, spare radios are not authorized for the combat unit or for the ERD at present; therefore, backorders are created at the combat units whenever broken radios are being shipped and repaired.

Under adverse combat conditions, the breakage rates for these radios and both transportation and repair times may increase, and accordingly backorders may increase also. The stockage level for radio spare components at the ERD is adequate at present to support the peacetime mission; however, the stockage level requirement for wartime (three times the peacetime demand rate) has never been validated or justified (9).

Overview of Dyna-METRIC Model

Dyna-METRIC is a computer inventory model designed to estimate the capability of a given component support system configuration with component related resources and with an aircraft flying hour (usually wartime) scenario (1:13). The Dyna-METRIC model was developed by the Rand Corporation to investigate how the planning and management of the Pacific Air Force's combat support system interfaces with the Air Force Logistics Command (AFLC) (1:1-4). This model is an extension of previous models developed by Rand to support special studies for the United States Air Force.

Among the early inventory models, the Multi-Echelon Technique for Recoverable Item Control (METRIC) model is capable of determining base and depot stock levels for a group of recoverable items (17:123). The METRIC model allowed managers to focus on the entire weapon system, instead of computing stock levels on the basis of expected pipeline quantities that are insensitive to cost so that an appropriate combination of system effectiveness and system cost can be selected (8). The METRIC model's logic was tested successfully at Hamilton Air Force Base in the late

1960s (17:123). This model was designed for application at the weapon system level, where an array or particular line items may be demanded at several bases, and where the bases are supported by one central depot (1; 2:41; 18).

The Mod-METRIC, a 1973 extension of the METRIC model has been implemented by the USAF as the method for computing recoverable spare stock levels for the F-15 weapon system. Mod-METRIC was designed for the control of a multi-item, multi-echelon, multi-indenture inventory system for recoverable items. The objectives of this model are to describe the logistics relationship between an assembly and its sub-assemblies and to compute spare stock level for both echelons for the assembly and sub-assemblies with explicit consideration of this logistics relationship. In particular, this model is used to determine the base and depot spare stock levels which minimize total expected base backorders for the assembly subject to a system investment constraint (2:42; 12:472).

Need for Dyna-METRIC. Logistics managers have been charged to assure their forces have adequate wartime capability. To achieve that objective, logisticians need information about how current component support systems contribute to capability, and about how alternate systems might improve capability. They need information that identifies those resources and processes that most constrain wartime capability. Their efforts are complicated by two features of the component support system: it is dynamic, and it is complex. Furthermore, logistics managers need information to forecast how component support resources and processes limit wartime capability across a wide range of wartime scenarios (1:1-6).

Physical System Modeled by Dyna-METRIC. Dyna-METRIC is a mathematical model of a reparable inventory system where there are several levels of repair and several levels of indenture. The indenture levels are restricted to only three levels of indenture--i.e., components are indentured to aircraft, sub-components are indentured to components, and sub-sub-components are indentured to sub-components.

Component and sub-component repair can occur at one of three levels (1:14-16). Each flight line has its own co-located Intermediate Level Maintenance Facility (ILM) and may be further supported by a Centralized Intermediate Repair Facility (CIRF). The depot impacts the performance of bases and CIRF through the resupply time required to obtain replacement stock. Resupply time represents forward transportation time plus any repair and handling time lag. Resupply time may vary between peacetime and wartime. Further, resupply may be cut off for some period during the conflict.

The above structure, in combination with input data detailing flying programs, component and sub-component relationships, and failure characteristics, is used by Dyna-METRIC in the construction of probability distributions that describe the disposition of components throughout the system on requested days.

Reports Available from Dyna-METRIC. The reports available from the Dyna-METRIC model can be divided into two major groups: reports on performance and reports on requirements for stock to achieve performance goals (1:16-17).

Reports on performance include:

1. List of problem components rank-ordered by probable impact;

2. Expected backorders of each component at each base;

3. Detailed pipeline tables indicating the expected disposition of each component throughout the theatre;

4. Resource workloads for those components assigned to Automatic Test Equipment (ATE);

5. Expected number of Non Fully Mission Capable (NFMC) aircraft by base under both full cannibalization and no cannibalization policies;

6. Expected number of Fully Mission Capable (FMC) sorties that each base can generate on selected days.

Requirements reports include recommended component and sub-component stock purchases to achieve individual item ready rates or an overall Not Mission Capable Supply (NMCS) goal, and a report on the required number of ATE to avoid queuing delays.

Assumptions for Dyna-METRIC

Although Dyna-METRIC maintains the capability to model real world events to an appreciable degree, it has its limitations (2:52-54; 12:474; 17:126-130; 18). The assumptions for the general Dyna-METRIC logic are described to facilitate descriptions of the model's capabilities. The model assumes:

1. Ample repair resources exist to assure that an item entering repair does so without delay.

2. Average repair times are stationary about their mean.

3. Repair processes at a base and its CIRF are identical.

4. Aircraft at each base are semi-homogeneous. The model also assumes that LRUs are interchangeable given cannibalization is permitted.

5. Lateral resupply is prohibited because this is mathematically difficult to integrate into the model.

6. LRU and SRU demand rates are not adjusted to reflect previous Fully Mission Capable (FMC) sorties accomplished. The model assumes that some Partially Mission Capable (PMC) aircraft will be used to fly sorties if FMC aircraft are not available.

7. The daily demand rates follow a Poisson probability distribution and are a function of time for each pipeline.

8. LRUs and SRUs fail at a given rate based on flying hours only.

9. Cannibalization policy is all or nothing. Under cannibalization, the model assumes the ability to instantly consolidate shortage onto the smallest number of aircraft or LRUs at no cost in terms of delay time.

10. Demands are not affected by environmental, organizational, and other differences between bases.

11. Only two levels of indenture.

12. No condemnations of LRUs. Battle damage or failures always can be repaired.

13. All aircraft are FMC at start of scenario (i.e., in our case, no broken radios at beginning of the war).

14. Maximum sortie rate can not vary between bases.

15. Only LRUs are problem parts. There is no performance data on indentured SRUs.

Problem and Dyna-METRIC Model

As described in the situation section in this chapter the nature of the maintenance radio issue can be studied by the Dyna-METRIC model. Dyna-METRIC has been tested successfully in the Tactical Air Command (TAC) and, in a sense, has been validated as estimating wartime capability for a given level of recoverable inventory (2:49). This research investigated maintenance radio capability via the Dyna-METRIC model by treating maintenance radios as an aircraft component. The methodology for this analysis as well as a discussion of the impact of assumptions and limitations are presented in Chapter III.

III. Methodology

Overview

The methodology for this research was to collect data on maintenance radio characteristics, to develop a hypothetical war scenario, and to input this information into the Dyna-METRIC model in order to fully answer the proposed research questions. Three items were needed in order to carry out this methodology. First, realistic data on maintenance radios and their components were needed in order to input into model. These data were provided by the HQ ROKAF. Second, a war scenario was needed as a model input to represent the wartime environment peculiar to the maintenance radio system. A hypothetical war scenario was created by this author to represent a typical war scenario so as to avoid working with classified information. Third, this study used Rand Corporation's Dyna-METRIC model (version 4.3) as the evaluation tool because of its sophistication and ability to model real world events and its capability to assess radio availability treating radios as an aircraft component rather than simply computing the expected numbers of backorders, as most recoverable model do. The research questions, then, were answered by combining data, the war scenario, and the Dyna-METRIC model.

Evaluation Model

The Dyna-METRIC model was used as the evaluation tool for this research. It is a validated, state-of-the-art recoverable model capable of both stock computation and performance evaluation. The problem of formulating data inputs is greatly simplified when a single model is capable of operating in both modes. The model was made available on AFLC's CREATE computer system. The model has been used by Ogden Air Logistics Center (ALC) and HQ Air Force Logistics Center (AFLC) to study USAF F-4 and F-16 aircraft readiness and supportability, and by TAC to study the effect of several repair and supply strategies affecting F-15 tactical squadrons (2:49).

Dyna-METRIC is powerful tool that allows researchers flexibility in setting-up experiments. It is a dynamic model in that the model allows researchers to conveniently study a variety of questions on the transient behavior (e.g., sortie rates, time-dependent failure rates) of the reparable inventory system under time-dependent operational demands. This dynamic feature provides the logistics managers with the ability to look at almost any potential combat environment and determine the shortfalls caused by inadequate logistics support (2:50).

Dyna-METRIC is capable of handling indentured relationships among recoverable items. A radio is made up of many components. If a radio is treated as a component of an aircraft, radio components could be considered as aircraft sub-components. The model is capable of predicting how many radios will fail and be sent to the ERD for repair with appropriate spare components.

In the stock computation mode, the model considers radio/component relationships and makes decisions to buy whatever quantity and mix of radios/components are cost optimal to achieve the desired radio availability level. The model is multi-echelon. It can handle the ten ROKAF bases and provide full capability to model the ERD. The specific relationship between bases and ERD can be easily modeled. The specific relationship between bases and ERD which we are interested in is that all failed radios must be sent to the ERD and that no intermediate level maintenance facility exists. Therefore, modeling these relationships is even simpler than another cases in which complex relationships have been modeled.

Dyna-METRIC provides only one set of outputs for a given set of input parameters because it is an analytic model. The outputs, however, are probabilistic in nature with expected values and standard deviations about each expected value. This is in contrast to a sampling notion using a simulation model. In simulation, a random number generator would induce different sets of input parameters for each run thereby producing different output results. Several runs would have to be completed in order to satisfy statistical sampling requirements. The nature of research using an analytic model such as Dyna-METRIC closely parallels a group of case studies. The benefit of using the analytic model in a multiple case study mode is that it reduces the time and resources required for a comparable confidence level. However, an analytic model is often limited by its assumptions.

Impacts of Dyna-METRIC Assumptions on the Experimental Design

Dyna-METRIC must make assumptions to simplify the mathematical relationships between elements in order to avoid becoming over-burdensome to the point of impracticalibility. The assumptions of Dyna-METRIC, as described in the previous chapter, set limitations on the capability of Dyna-METRIC to model real world events and also impact on the experimental design of this research.

For example, the model assumes that ample repair resources exist to assure that the average repair time remains relatively constant and is stationary about its mean. In reality, the total repair time (from shipping radio to ERD until receiving it) depends on the availability of repair and spare parts resources. When more radios have queued up for repair, the average total repair time (i.e., including queuing and "hand-on" repair time) for radios increases. As more repair capability (personnel, equipment, facilities, procedures, and training) becomes available, queuing time and quantity decrease. The model, however, cannot provide information about how additional repair resources mav improve repair, so it implicitly assumes that ample repair resources exist to assure that the average repair time remains relatively constant. This assumption is violated when wartime demand and support resources fluctuate dramatically. Thus, the model may underestimate the degradation of wartime availability of maintenance radio by ignoring queue delay time.

Another assumption is that lateral resupply is prohibited. The model assumes lateral resupply is prohibited because it is mathematically difficult to integrate into the model, and hence logistics capability is underestimated because with lateral resupply, delay times are reduced. However, in our case, resupply of radios between bases is impossible because each base is not authorized to stock any spare radios. Each base is expected to have a deficiency in available radios from the beginning of the scenario.

The model assumes the daily demand rates follow a Poisson probability distribution and are a function of time for each pipeline. Failure and repair processes are typically not deterministic, so, the actual number of radios in a pipeline may vary widely from the expected value. Hillestad and Carrillo demonstrate that the number of items in repair would follow a non-homogeneous Poisson probability distribution, so long as the daily demands were Poisson and the repairs were either deterministic or exponential (8). To compute a non-homogeneous Poisson distribution, one needs only its daily mean or expected value. Thus, the model uses the expected daily pipeline quantity of radios to compute the cumulative probability distribution necessary for radio availability computations.

The model assumes that component/sub-component demand rates depend solely on flying hours consumed at each operating location. Thus, components fail more frequently when aircraft flying is high than when it is low. Although it would seem that the demand rate for radios depends less on flying hours than on sorties, it can be converted into an equivalent flying hours demand rate, given the average sortie length expected in the scenario.

From the general assumptions shown in Chapter II, we have examined above those which are pertinent to the maintenance radio issue. The remaining assumptions are not germane to this issue.

Research Data Collection and Scenario

Descriptive data for maintenance radios were obtained from the HQ ROKAF and the ERD. These data contain characteristics of radios and their components based on three years experience with maintenance radios. These data contain details on two types of radios each with 14 and 11 critical components respectively. Hundreds of other non critical components were eliminated from the data because they have not impacted the availability of radios for various reasons i.e., some of them have not broken for the three year period or some of them are purchasable domestically (13). Radio data include brand names, types of radios, peacetime demand rates per flying hour, number of radios which are assigned to each base, unit price, and peacetime average repair time at the ERD. Currently the ROKAF does not specifically track the information necessary to readily determine the cannibalization feasibility, demand rate per flying hour, and repair time at the ERD. Therefore, these data were available only after personal contact with individuals who have had radio maintenance experience from the beginning of maintenance radio implementation. Data on the radio components include noun, peacetime demand rates per flying hour, unit price, quantities per each radio, and average peacetime stock levels at the ERD.

The war scenario used for this research was developed by the author to represent a realistic war scenario because it was infeasible to use a classified war scenario. Although using hypothetical scenario data is less realistic, it satisfies the objective of this research--to provide a methodological approach for determining wartime requirements for maintenance radios and their components.

The scenario consists of ten bases (eight with one type of radio and two with another type) supported by a single depot. Flying hour surge per sortie per aircraft per day was held constant for each base for the entire period. The bases send inoperative radios to the ERD using a "Remove and Replace" maintenance concept. Bases do not repair radios for the entire scenario. The depot operates solely from its on-hand components stock and is not resupplied by vendors with radios or components for the entire period. Other various Dyna-METRIC input factors (i.e., aircraft attrition, intermediate level maintenance, centralized intermediate repair facility, test stand) are not necessary in this scenario (9).

Research Data Preparation

As was mentioned in the previous section, the ROKAF does not track all the information necessary to provide input directly to Dyna-METRIC model. This constraint, along with the difficulties of contact and time restrictions involved in collecting the necessary information, required some assumptions to prepare the data into a usable form.

Although cannibalization provides an additional source of spare components in the face of supply shortages, cannibalization is not a common practice in the ROKAF maintenance radio service system for various reasons. For example, the structure and material strength of radio components usually does not allow cannibalization (13).

Even among those components considered to be cannibalizable, there is a risk of damaging them during cannibalization which would create additional broken components. It may result in the expenditure of service resources (especially manpower) above what is normally authorized to accomplish service requirements. However, cannibalization can not be avoided when there is a high probability of stockout in wartime (9).

Data on components provided by the ROKAF does not include information on whether they are cannibalizable. Telephone interviews with individuals at the ERD indicated that most components we are concerned with are in fact cannibalizable (3). Therefore, an assumption was made that all radio components are cannibalizable. This assumption facilitates data input which permits either no cannibalization or full cannibalization of SRUs for each LRU.

TABLE 1

Radios and Their Components

Type Radio	Number of Components	Number of Critical Components under Research	Percentage %
UHF	158	14	8.8
VHF	132	11	8.3

Data were provided for two different types of maintenance radios. They have different manufacturers, frequency bands, and transmission power. More than hundred components make up each radio as shown in Table 1.

The component data were examined to reduce the data base while retaining only the more important data for the analysis. The elimination of the less important data was first based on the availability of a domestic market place. If any component was manufactured or purchasable domestically, it was eliminated from the data base because we can presume it would be available during wartime. Many electrical components such as capacitors, diodes, fuses, and resistors were included in this category.

The historical demand for each component was also considered. For some components, the initial supply which was intended to last one year has never been depleted. Moreover, there are some components that have never failed. These less important components are not critical to the ROKAF radio maintenance effort (13). Thus, they are eliminated from this research.

Based on information supplied by the ROKAF, we contrived a war scenario with ten bases each with different ratios between numbers of radios and aircraft. To distinguish the actual numbers of radios at each base within Dyna-METRIC, the number of radios was divided by number of aircraft for each base to obtain a Quantity Per Aircraft (QPA) value. In the Dyna-METRIC model, however, QPA is a constant for each aircraft. Thus, the next integer of the largest dividend obtained from above divisions, which is two, is the QPA for each type of radio.

In order to have the model reflect the correct number of radios at each base we had to resort to an Application Fraction Factor. After QPA was determined, an Application Fraction Factor was calculated for each base with the following formula:

$$\text{Application Fraction Factor for Each Base} = \frac{\text{Number of Radios}}{\text{QPA}(=2) \times \text{Number of Aircraft}}$$

Table 2 and Table 3 reflect Application Fraction Factor calculations for each base.

TABLE 2

Application Fraction Factor
(UHF)

Bases	Number of Aircraft (A)	(A) x 2 = (B)	Number of Radios (C)	(C)/ (A)	Application Fraction Factor=(C)/(B)
BA11	52	104	76	1.46	.731
BB12	51	102	76	1.49	.745
BC21	70	140	83	1.19	.593
BD22	69	138	83	1.20	.601
BE23	72	144	83	1.15	.576
BF24	71	142	83	1.17	.585
BG25	68	136	80	1.18	.588
BJ41	28	56	50	1.79	.893

TABLE 3

Application Fraction Factor (VHF)

Bases	Number of Aircraft (A)	(A) x 2 =(B)	Number of Aircraft (C)	(C)/ (A)	Application Fraction Factor=(C)/(B)
BH31	52	104	98	1.88	.942
BI32	56	112	98	1.75	.875

The Application Fraction Factor specifies the fraction of each base's aircraft that contain a given type of radio. The higher the Application Fraction Factor (close to one) then relatively more radios are assigned to the base. It also implies that radios will be used more often and hence will fail more frequently.

Obtaining historical demand data for radios and their components was achieved through supply records kept by the ERD. These records list radio and component demand for a three year period. The number of flying hours corresponding to this same time period was provided by the HQ ROKAF. From this information, the demand per flying hour could be computed for each radio and its components via the following formula:

$$\text{Mean Time Between Demand (MTBD)} = \frac{\text{Total Hours Flown} \times \text{Quantity Per End Item}}{\text{Total Demand}}$$

$$\text{Demand Per Flying Hour} = \frac{1}{\text{MTBD}}$$

Experimental Design

Calculating the quantities of spare radio components needed to cover consumption in repairing radios and the quantities of radio backorder in the total pipeline was the major task of this research. The experimental design developed for this research was a simple process.

The data provided by the ROKAF and the contrived war scenario were prepared according to the Dyna-METRIC (version 4.3) input format. Because two different types of radios were assigned (but only one type to each base) and no interchangeable components exist (9), the model was run twice--once for each type of radio. The model was run to represent a period of 30 days of wartime activity. The model could be run much longer, but those analyses were beyond the scope of this research. The desired FMC aircraft level was set at 80 per cent with 80 per cent confidence level which is common practice with Dyna-METRIC analysis in the USAF's Tactical Air Command and also coincides with minimum requirement levels for the ROKAF (9). As indicated in the previous chapter, the Dyna-METRIC does not provide performance data on SRUs (radio components). Thus, the consumption of radio spare parts could not be obtained directly from the Dyna-METRIC output. Since this information is required to answer research questions one and two, we must resort to the following scheme using a depot replacement percentage obtained from the HQ ROKAF. These replacement percentages (recorded in Tables 14 and 15) represent the proportion of radio failures which are attributable to specific SRU failures. We, then, multiply the number of AWP radios (assuming no cannibalization) by the replacement percentages to impute a quantity of failed radio components.

With this design, the quantities of consumed/required spare radio components to cover 80 per cent FMC aircraft level were compared with quantities of peacetime demands multiplied by the factor of three thereby answering the proposed first research question: Are there sufficient quantities of radio spare components authorized for wartime stockage at the ERD?

Research question two stated: If the authorized spare part stock are not correct, what changes in authorized stock levels are in order? Recall that the authorized wartime stocks are based on peacetime demand multiplied by a factor of three. Of course, we can develop wartime radio component requirements from the procedures above using the depot replacement percentage data. We can also use this information and adjust the factor of three (multiplied by peacetime demand) to some other factor which would provide the expected wartime consumption given a constant level of peacetime demand.

When run in the performance evaluation mode, the Dyna-METRIC model estimates expected numbers of backorders of radios in the entire pipeline as well as performance measures for each designated day of the scenario. This number of backordered radios is compared with the allowable level of 20 per cent for each base to answer the last research question: Should spare radio be authorized for the combat units in order to compensate for possible increase in the number of radios in the repair pipeline? If so, how many spare radios are required for each combat unit?

Methodology and Design Limitations

In addition to the Dyna-METRIC and data base assumptions previously discussed, there are certain assumptions associated with the methodology and experimental design that have not been examined. The discussion that follows will lay the necessary foundation upon which valid analysis and interpretation of the results will be possible.

First, because the maintenance radios are not really aircraft components, the demand rate is not necessarily driven by flying hour intensity. However, our methodology and experimental design assumes it is a function of flying hour intensity. The results must be interpreted with the assumption that the demand rates depend solely on flying hour.

Second, because the war scenario developed by the author does not reflect any real world parameters, the results must not be interpreted or used as a clue to understanding the capability of the ROKAF. Therefore, we want to emphasize that this is a methodological approach for determining wartime requirements for non aircraft components rather than an actual capability determination.

IV. Results

Overview

The contents of the Dyna-METRIC output depend on options selected by the user, but they are generally quite extensive. Unless suppressed, Dyna-METRIC provides an echo of the problem description specified in the input data. Like the original input problem description, the echo of inputs are organized into blocks of related information. Those blocks echo the administrative information, depot and base description, flying program for base, and detailed radio and component information. Dyna-METRIC may also provide error messages in the output. Any error in the input causes termination of model operation after all of the problem description is read.

We selected options that produced output consisting of: detailed pipeline segment status at the depot on each day, performance based on stock on hand on each day, and a problem parts list on each day. The performance report based on stock on hand in turn consisted of the probability of achieving the target rate for NMCS, the probability of achieving the target sorties, the expected number of NMCS aircraft, the expected number of sorties flown for both the full and partial cannibalization assumptions, and the expected backorders.

From this output, we are interested in expected radio backorders in the performance report and radio AWPs in the detailed pipeline segment report for the depot. Since the amount of meaningful information needed for analysis is such a small part of the output provided, rather than include extensive computer listing, this information is summarized below.

Presentation of Research Results

Tables 4 through 7 present information on the expected number of available radios from two separate Dyna-METRIC analyses (with full cannibalization) designed to answer the last research question. ailable radios for each base on day 30 of the scenario are shown in Tables 6 and 7. Research questions one and two required two additional Dyna-METRIC analyses without cannibalization to obtain the required number of radio components. Tables 8, 9, 12, and 13 summarize results of the above runs. The authorized wartime stockage level for spare radio components is compared with consumed/required components for a 30 day period in Tables 14 and 15 to answer research question one. Tables 16 and 17 present the new factors for the second research question.

TABLE 4

Radio Backorders
(Cannibalization)
(UHF)

Base	Days					
	5	10	15	20	25	30
BA11	2.24	2.62	2.83	3.08	3.36	3.67
BB12	2.24	2.61	2.83	3.08	3.36	3.67
BC21	2.67	2.61	3.89	3.36	3.67	4.01
BD22	2.66	2.86	3.09	3.36	3.67	4.00
BE23	2.66	2.86	3.09	3.36	3.67	4.00
BF24	2.67	2.86	3.09	3.37	3.67	4.01
BG25	2.57	2.75	2.98	3.24	3.54	3.86
BJ41	0.80	0.82	0.89	0.96	1.05	1.15
Total	18.50	20.24	21.88	23.81	25.99	28.36

TABLE 5

Radio Backorders
(Cannibalization)
(VHF)

Base	Days					
	5	10	15	20	25	30
BH31	5.08	5.51	5.93	6.43	7.00	7.63
BI32	5.08	5.52	5.93	6.43	7.00	7.64
Total	10.16	11.03	11.86	12.86	14.00	15.27

TABLE 6

Available Radios on Day 30
(Cannibalization)
(UHF)

Base	Number of Radios (A)	Desired Number of Radios (B) = (A) x .8	Backorders (C)	Available Radios (A) - (C)
BA11	76	60.8	3.67	72.33
BB12	76	60.8	3.67	73.33
BC21	83	66.4	4.01	78.99
BD22	83	66.4	4.00	79.00
BE23	83	66.4	4.00	79.00
BF24	83	66.4	4.01	78.99
BG25	80	64.0	3.86	76.14
BJ41	50	40.0	1.15	48.85
Total	614	491.2	28.36	585.64

TABLE 7

Available Radios on Day 30
(Cannibalization)
(VHF)

Base	Number of Radios (A)	Desired Number of Radios (B) = (A) x .8	Backorders (C)	Available Radios (A) - (C)
BH31	98	78.4	7.63	90.37
BI32	98	78.4	7.64	90.36
Total	196	156.8	15.27	180.73

TABLE 8

Radio Backorders
(No Cannibalization)
(UHF)

Base	Days					
	5	10	15	20	25	30
BA11	3.24	4.14	4.95	5.72	6.59	7.56
BB12	3.23	4.13	4.95	5.72	6.59	7.55
BC21	4.30	4.77	5.41	6.25	7.20	8.25
BD22	4.29	4.76	5.41	6.24	7.19	8.24
BE23	4.29	4.76	5.41	6.24	7.19	8.24
BF24	4.30	4.77	5.42	6.25	7.20	8.26
BG25	4.14	4.59	5.21	6.02	6.93	7.95
BJ41	1.34	1.40	1.55	1.79	2.06	2.37
Total	29.14	33.33	38.31	44.22	50.95	58.42

TABLE 9

Radio Backorders
(No Cannibalization)
(VHF)

Base	Days					
	5	10	15	20	25	30
BH31	11.58	12.91	14.56	16.51	18.79	21.30
BI32	11.58	12.92	14.56	16.52	18.78	21.31
Total	23.16	25.83	29.12	33.03	37.55	42.61

TABLE 10

Detailed Pipeline Segment
(Cannibalization)
(UHF)

Days	Total Backorders	AWPs	Total Backorders - AWPs
5	18.50	3.68	14.82
10	20.24	4.80	15.44
15	21.88	6.25	15.63
20	23.81	7.99	15.82
25	25.99	9.95	16.04
30	28.36	12.10	16.26

TABLE 11

Detailed Pipeline Segment
(Cannibalization)
(VHF)

Days	Total Backorders	AWPs	Total Backorders - AWP
5	10.16	2.87	7.29
10	11.03	3.47	7.56
15	11.86	4.23	7.63
20	12.86	5.13	7.73
25	14.00	6.17	7.83
30	15.27	7.32	7.95

TABLE 12

Detailed Pipeline Segment
(No Cannibalization)
(UHF)

Days	Total Backorders	AWPs	Total Backorders - AWPs
5	29.14	14.60	14.54
10	33.33	18.50	14.83
15	38.31	23.42	14.89
20	44.22	29.24	14.98
25	50.95	35.88	15.07
30	58.42	43.22	15.20

TABLE 13

Detailed Pipeline Segment
(No Cannibalization)
(VHF)

Days	Total Backorders	AWPs	Total Backorders - AWPs
5	23.16	16.07	7.09
10	25.83	18.71	7.12
15	29.12	22.02	7.10
20	33.03	25.94	7.09
25	37.55	30.43	7.12
30	42.61	35.46	7.15

TABLE 14

Consumed/Required Components
(UHF)

Component Name	Replacement Percentage (A)	AWPs x (A) (B)	Stock on Hand (C)	Required Components (B) + (C)
5820L055237	0.106	4.58	8	12.58
5820L055319	0.089	3.85	7	10.85
5820L055878	0.212	9.16	16	25.16
5829L040270	0.116	5.01	9	14.01
5910L040381	0.055	2.38	4	6.38
5910010650391	0.021	0.91	2	2.91
5961010061399	0.034	1.47	5	6.47
5820L044354	0.034	1.47	3	4.47
5820L040355	0.038	1.64	3	4.64
5945L040397	0.060	2.59	9	11.59
5945L040394	0.099	4.28	7	11.28
5820L040278	0.086	3.72	6	9.72
5820L040279	0.243	10.50	18	20.50
5820L040280	0.253	10.93	19	29.93

TABLE 15

Consumed/Required Components
(VHF)

Component Name	Replacement Percentage (A)	AWPs x (A) (B)	Stock on Hand (C)	Required Components (B) + (C)
5820L057846	0.100	3.55	4	7.55
5820L055321	0.063	2.23	2	4.23
5820L055880	0.150	5.32	6	11.32
5820L040273	0.088	3.12	3	6.12
5910010650395	0.081	2.87	7	9.94
5910010650397	0.125	4.43	5	9.43
5961010061421	0.144	5.11	11	16.11
5820L040356	0.075	2.66	2	4.66
5950L031065	0.113	4.01	4	8.01
5765L040411	0.100	3.55	4	7.55
5820L043305	0.275	9.75	11	20.75

TABLE 16

New Factors
(UHF)

Component Name	Required Components (A)	Peacetime Demand Rate for 30 Days (B)	New Factors (A)/(B)
5820L055237	12.58	2.58	4.88
5820L055319	10.85	2.17	5.00
5820L055878	25.16	5.17	4.87
5820L040270	14.01	2.83	4.95
5910L040381	6.78	1.33	4.80
5910010650391	2.91	0.50	5.82
5961010061399	6.47	1.67	3.87
5820L040354	4.47	0.83	5.38
5820L040355	4.64	0.92	5.04
5945L040397	11.59	2.92	3.97
5945L040394	11.28	2.42	4.66
5820L040278	9.72	2.08	4.67
5820L040279	20.50	5.92	3.46
5920L040280	29.93	6.17	4.85

TABLE 17

New Factors
(VHF)

Component Name	Required Components (A)	Peacetime Demand Rate for 30 days (B)	New Factors (A)/(B)
5820L057846	7.55	1.33	5.68
5820L055321	4.23	0.67	6.31
5820L055880	11.32	2.00	5.66
5820L040273	6.12	1.00	6.12
5910010650395	9.94	2.33	4.27
5910010650397	9.43	1.67	5.65
5961010061421	16.11	3.67	4.39
5820L040356	4.66	0.67	6.96
5950L031065	8.01	1.33	6.02
5765L040411	7.55	1.33	5.68
5820L043305	20.75	3.67	5.65

Analysis of Results

The original data base of UHF and VHF radios consisted of 158 and 132 components respectively. However, 14 and 11 components respectively were selected as having critical impacts on the performance of the maintenance radios. Though this data base contained less than 10 per cent of components, the selected components are most likely to affect the performance of maintenance radios and to lead to meaningful results. The results showed for our contrived scenario that the present supply and maintenance policies may not cause significant problems in maintaining the desired level of performance.

Research Question 1. The number of required radio components can be seen by looking at the last columns in Tables 14 and 15. Column 3 of both tables show the amount by which consumed components exceeded the current level of wartime support (three times peacetime demand). Therefore, insufficient stock quantities were believed to decrease the availability of serviceable maintenance radios.

Research Question 2. Given this large deficiency in the authorized stock level, it is important to determine what is an appropriate factor to be multiplied by peacetime demand. As shown in the Table 16, revised factors for UHF are calculated by dividing required components by peacetime demand for the same period of 30 days. Table 17 shows the same calculations for VHF radios.

Research Question 3. The last column of both Tables 4 and 5 presents the results of Dyna-METRIC analyses on the backordered radios at each base on day 30 of the war scenario. The desired level of radios is 80 per cent of radios assigned to each base which is the minimum level determined by the ROKAF to permit normal operations. The results show that total pipeline quantities do not exceed 20 per cent of total radios regardless of the cannibalization policy.

V. Conclusions

Summary of Research Effort

The maintenance intrabase radio nets are essential elements to the operational capability of the ROKAF. The anticipated capability of the maintenance radio net is greatly dependent upon adequate logistics support. However, no spare radios are authorized for the combat units or for the ERD, and the authorized wartime stockage levels for spare radio components are determined simply by multiplying the peacetime demand rate by a factor of three. Until now, the potential impacts that logistics support may have on the availability of radios has not been investigated by quantitative techniques. It is important to understand the impact of the logistics support in order to assure adequate wartime availability of maintenance radio.

This research developed a methodology to enable the ROKAF to estimate the wartime availability of its maintenance radios. The methodology consisted of treating maintenance radios as LRUs each with multiple SRUs and a 100 per cent NRTS rate and analyzing the availability of them with the Dyna-METRIC model under a hypothetical war scenario. The major effort of the research was to obtain and prepare the necessary data for Dyna-METRIC analysis. Additional information was required to prepare data that the

ROKAF does not actively track such as radio/component demand per flying hour, repair time at depot, transportation time between bases and depot, administrative delay, and cannibalization feasibility.

Results on the two different types of radios showed that inadequately stocked spare components and no authorized spare radio for the bases or for the depot attributed equally to backorders throughout a thirty-day scenario.

Conclusions

Research Question 1. The expected level of available radios at the combat unit can be significantly reduced if adequate stock levels for spare components are not accurately identified and maintained. With this research, a methodology now exists to estimate the impact of the stock level for spare components. As the results suggest, all critical spare components may be inadequately stocked, and these insufficient stock levels may reduce the number of available radios under a war scenario.

Research Question 2. All critical spare components were under-stocked to some degree. Rather than the old multiplication factor of three, new multiplication factors were calculated as a function of the type of radio and each component. Different application fraction factors contributed to the different ranges between two types of radios. The application fraction factors added reality to the model via assuming different levels of utilization.

Research Question 3. The expected level of backorders for radios at the combat unit can be significantly reduced if adequate spare radios were authorized to compensate for pipeline quantities. Since there was no transportation cutoff between bases and depot and relatively ample repair resources, a relatively constant number of radios were tied up in the pipeline but AWP radios. If additional UHF and VHF radios are authorized then they would offset the loss of capability represented by these pipeline quantities.

Recommendations

Current and proposed wartime inventory stockage policies for some non-aircraft components such as maintenance radios have not been evaluated by quantitative techniques. As stated earlier, the Dyna-METRIC model provides the necessary framework from which critical decisions directly impacting operational readiness for those non-aircraft component can be made. Because it has been shown that current wartime stock levels for the maintenance radio may be subject to error, it is recommended that an analysis similar to the methodology developed in this research be implemented to verify stock levels of these and other non-aircraft components.

In this research, only wartime stock levels for maintenance radios and their components have been evaluated, but the extensive capability of the Dyna-METRIC model permits evaluation of further alternatives to improve performance. Sometimes, alternatives exist that do not require more stock. For example, one may be able to reduce the repair time. Faster repair should decrease the repair pipeline size and reduce the number of inoperative radios. The quantity of radios and their components is dependent upon the maintenance concept employed. This concept which may be designated as Remove and Repair (RR) in peacetime can be redesignated as Remove, Repair, and Replace (RRR) if the item can be easily repaired at the base maintenance level with a few additional wartime augmentation maintenance resources. In other cases, it may be possible to decrease transportation time between bases and depot. In determining which combination of alternatives to use, tradeoffs must be made between equipment, personnel, spares, repair parts, and transportation requirements.

However, most importantly some of the data that was required in this research are not currently tracked by the ROKAF. A cost/benefit analysis is needed to determine the feasibility of incorporating the needed data (e.g., demand per operating hour, cannibalization feasibility, repair time, and transportation time) into the existing data base. In summary, the results of this research emphasize the need for the development and use of sophisticated techniques to evaluate current and proposed logistics support.

Appendix A: Acronym Definition

AFLC	--	Air Force Logistics Command
ALC	--	Air Logistics Center
ATE	--	Automatic Test Equipment
AWP	--	AWaiting Part
CIRF	--	Centralized Intermediate Repair Facility
ERD	--	Electronics Repair Depot, ROKAF
FMC	--	Full Mission Capable
HQ	--	Headquarters
ILM	--	Intermediate Level Maintenance
LRU	--	Line Replaceable Unit
METRIC	--	Multi-Echelon Technique for Recoverable Item Control
MTBD	--	Mean Time Between Demand
NFMC	--	Not Full Mission Capable
NMC	--	Not Mission Capable
NMCS	--	Not Mission Capable Supply
NRTS	--	Not Reparable This Station
PACAF	--	Pacific Air Force, USAF
PMC	--	Partial Mission Capable
QPA	--	Quantity Per Aircraft
ROKAF	--	Republic Of Korea Air Force
RR	--	Remove and Replace
RRR	--	Remove, Replace, and Repair
SRU	--	Shop Replaceable Unit

TAC -- Tactical Air Command

UHF -- Ultra High Frequency

USAF -- United States Air Force

VHF -- Very High Frequency

Appendix B: Sample Input Format (Version 4.3)

```
A DYNA-METRIC ANALYSIS OF THE ROK AIR FORCE M-RADIO REQUIREMENT
11    1.          1.                    MT1MT2MT3MT4MT5
   1    5   10   15   20   25   30
OPT
       8   1
      11   1   .80
      15
      18
DEPT
ERDK                                         46.1  60.   10.    1.    1.    50
BASE
BH31                                         46.1  60.   10.    1.   50.   100
BI32                                         46.1  60.   10.    1.   50.   100
TRNS
BH31 ERDK      1.     1. 1     1.  60.    10.
BI32 ERDK      1.     1. 1     1.  60.    10.
ACFT
BH31  52
BI32  56
TURN
BH31  2.    1  5.
BI32  2.    1  5.
FLHR
BH31 1.5   11.67
BI32 1.5   11.67
SRTS
BH31 1.5   1   4.
BI32 1.5   1   4.
LRU
5895L038715WTVHF ERDK 3    2  2 1 .00115                 1.0     0
5895L038715WTVHF                .167   6. .032 100.   46.      1352
APPL
5895L038715WTVHF BH31 .942 BI32 .875
SRU
5820L057846      ERDK 3    2    1 .00012
5820L057846                          0.  1.0 100.   46.       124
5820L055321      ERDK 3    2    1 .00007
5820L055321                          0.  1.0 100.   46.       135
5820L055880      ERDK 3    2    1 .00017
5820L055880                          0.  1.0 100.   46.        30
5820L040273      ERDK 3    2    1 .00010
5820L040273                          0.  1.0 100.   46.       145
5910010650395    ERDK 3    4    1 .00009
5910010650395                        0.  1.0 100.   46.         5
5910010650397    ERDK 3    2    1 .00015
5910010650397                        0.  1.0 100.   46.         5
```

```
5961010061421     ERDK 3     4     1 .00017
5961010061421                           0.   1.0 100.   46.          1
5820L040356       ERDK 3     2     1 .00009
5820L040356                             0.   1.0 100.   46.         45
5950L031065       ERDK 3     2     1 .00013
5950L031065                             0.   1.0 100.   46.         11
5765L040411       ERDK 3     2     1 .00012
5765L040411                             0.   1.0 100.   46.        120
5820L043305       ERDK 3     2     1 .00032
5820L043305                             0.   1.0 100.   46.         59
INDT
5895L038715WTVHF1L
5820L057846      OS   1 .1001
5820L055321      OS   1 .0625
5820L055880      OS   1 .1501
5820L040273      OS   1 .0876
5910010650395    OS   2 .0813
5910010650397    OS   1 .1251
5961010061421    OS   2 .1439
5820L040356      OS   1 .0750
5950L031065      OS   1 .1126
5765L040411      OS   1 .1001
5820L043305      OS   1 .2752
STK
5895L038715WTVHF ERDK     0 BH31     0 BI32     0
5820L057846      ERDK     4 BH31     0 BI32     0
5820L055321      ERDK     2 BH31     0 BI32     0
5820L055880      ERDK     6 BH31     0 BI32     0
5820L040273      ERDK     3 BH31     0 BI32     0
5910010650395    ERDK     7 BH31     0 BI32     0
5910010650397    ERDK     5 BH31     0 BI32     0
5961010061421    ERDK    11 BH31     0 BI32     0
5820L040356      ERDK     2 BH31     0 BI32     0
5950L031065      ERDK     4 BH31     0 BI32     0
5765L040411      ERDK     4 BH31     0 BI32     0
5820L043305      ERDK    11 BH31     0 BI32     0
END
```

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This research develops a methodology to investigate the impact that current logistics support policies have on the Republic of Korea Air Force's maintenance intrabase radio net using Rand's Dyna-METRIC inventory model. Current stockage policies for radios and their components were analyzed using a hypothetical war scenario. The results of this study reveal that the authorized stock levels for radio components may be inadequate thereby reducing serviceable radios in a conflict. The methodology developed for this research is applicable to many non-aircraft components.